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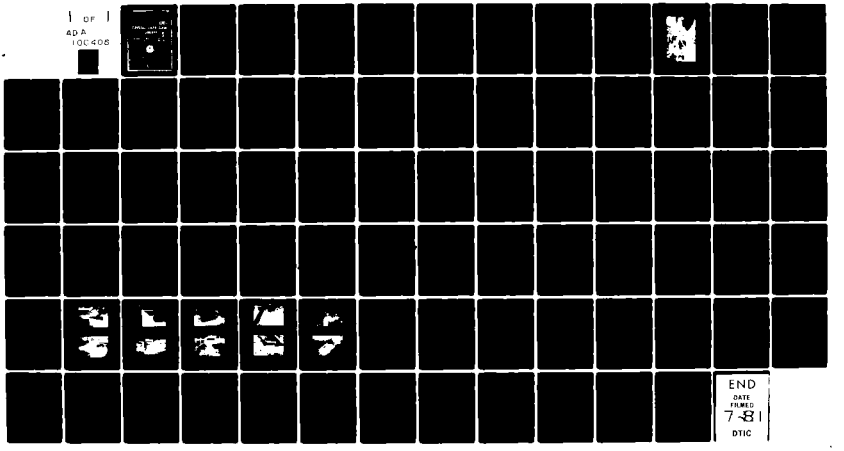

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DELAWARE RIVER BASIN,
TRIBUTARY TO DELAWARE RIVER,
BURLINGTON COUNTY,
NEW JERSEY.

LEVEL II

National Dam Safety Program.

CRYSTAL LAKE DAM

NJ00299

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PHASE I INSPECTION REPORT.
NATIONAL DAM SAFETY PROGRAM

(15) DACW61-79-C-0011

(9) Final rep't.,

(10) Richard J./McDermott
John E./Gribbin

(11) Jun 81 (12) 78

DEPARTMENT OF THE ARMY
Philadelphia District
Corps of Engineers
Philadelphia, Pennsylvania

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Dams	National Dam Safety Program
Embankments	Crystal Lake Dam, NJ
Visual Inspection	Riprap
Structural Analysis	Outlet works

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report cites results of a technical investigation as to the dam's adequacy. The inspection and evaluation of the dam is as prescribed by the National Dam Inspection Act, Public Law 92-367. The technical investigation includes visual inspection, review of available design and construction records, and preliminary structural and hydraulic and hydrologic calculations, as applicable. An assessment of the dam's general condition is included in the report.

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DEPARTMENT OF THE ARMY
PHILADELPHIA DISTRICT, CORPS OF ENGINEERS
CUSTOM HOUSE—2 D & CHESTNUT STREETS
PHILADELPHIA PENNSYLVANIA 19106

IN REPLY REFER TO
NAPEN-N

5 JUN 1981

Honorable Brendan T. Byrne
Governor of New Jersey
Trenton, New Jersey 08625

Dear Governor Byrne:

Inclosed is the Phase I Inspection Report for Crystal Lake Dam in Burlington County, New Jersey which has been prepared under authorization of the Dam Inspection Act, Public Law 92-367. A brief assessment of the dam's condition is given in the front of the report.

Based on visual inspection, available records, calculations and past operational performance, Crystal Lake Dam, initially listed as a high hazard potential structure, but reduced to a significant hazard potential structure as a result of this inspection is judged to be in good overall condition and the spillway is considered adequate. To ensure adequacy of the structure, the following actions, as a minimum, are recommended:

a. The following actions should be initiated within six months from the date of approval of this report:

(1) The outlet works should be investigated with respect to operational adequacy and, if necessary, restored to proper operational condition.

(2) Rusted CMP surface drain pipe should be replaced by proper inlet and pipe.

(3) Erosion of the embankment adjacent to the upstream wingwalls of the bridge should be properly stabilized.

(4) Deteriorating riprap on the upstream and downstream faces of embankment should be repaired where necessary.

(5) All trees and adverse vegetation on the embankment should be removed.

NAPEN-N
Honorable Brendan T. Byrne

b. The owner should develop an emergency action plan together with an effective warning system outlining actions to be taken by the operator to minimize downstream effects of an emergency at the dam within six months from the date of approval of this report.

c. The owner should develop written operating procedures and a periodic maintenance plan to ensure the safety of the dam within one year from the date of approval of this report.

A copy of the report is being furnished to Mr. Dirk C. Hofman, New Jersey Department of Environmental Protection, the designated State Office contact for this program. Within five days of the date of this letter, a copy will also be sent to Congressman Smith of the Fourth District. Under the provision of the Freedom of Information Act, the inspection report will be subject to release by this office, upon request, five days after the date of this letter.

Additional copies of this report may be obtained from the National Technical Information Services (NTIS), Springfield, Virginia 22161 at a reasonable cost. Please allow four to six weeks from the date of this letter for NTIS to have copies of the report available.

An important aspect of the Dam Inspection Program will be the implementation of the recommendations made as a result of the inspection. We accordingly request that we be advised of proposed actions taken by the State to implement our recommendations.

Sincerely,

Kenneth R. Moser

1 Incl
As stated

KENNETH R. MOSER
Major, Corps of Engineers
Acting Commander and District Engineer

Copies furnished:
Mr. Dirk C. Hofman, P.E., Deputy Director
Division of Water Resources
N.J. Dept. of Environmental Protection
P.O. Box CN029
Trenton, NJ 08625

Mr. John O'Dowd, Acting Chief
Bureau of Flood Plain Regulation
Division of Water Resources
N.J. Dept. of Environmental Protection
P.O. Box CN029
Trenton, NJ 08625

CRYSTAL LAKE DAM (NJ00299)

CORPS OF ENGINEERS ASSESSMENT OF GENERAL CONDITIONS

This dam was inspected on 9 January 1981 by Storch Engineers, under contract to the State of New Jersey. The State, under agreement with the U.S. Army Engineer District, Philadelphia, had this inspection performed in accordance with the National Dam Inspection Act, Public Law 92-367.

Crystal Lake Dam, initially listed as a high hazard potential structure, but reduced to a significant hazard potential structure as a result of this inspection is judged to be in good overall condition and the spillway is considered adequate. To ensure adequacy of the structure, the following actions, as a minimum, are recommended:

a. The following actions should be initiated within six months from the date of approval of this report:

(1) The outlet works should be investigated with respect to operational adequacy and, if necessary, restored to proper operational condition.

(2) Rusted CMP surface drain pipe should be replaced by proper inlet and pipe.

(3) Erosion of the embankment adjacent to the upstream wingwalls of the bridge should be properly stabilized.

(4) Deteriorating riprap on the upstream and downstream faces of embankment should be repaired where necessary.

(5) All trees and adverse vegetation on the embankment should be removed.

b. The owner should develop an emergency action plan together with an effective warning system outlining actions to be taken by the operator to minimize downstream effects of an emergency at the dam within six months from the date of approval of this report.

c. The owner should develop written operating procedures and a periodic maintenance plan to ensure the safety of the dam within one year from the date of approval of this report.

APPROVED: Kenneth R. Moser

KENNETH R. MOSER
Major, Corps of Engineers
Acting Commander and District Engineer

DATE: 4 June 1981

PHASE I REPORT
NATIONAL DAM SAFETY REPORT

Name of Dam:	Crystal Lake Dam, I.D. NJ00299
State Located:	New Jersey
County Located:	Burlington
Drainage Basin:	Delaware River
Stream:	Tributary to Delaware River
Date of Inspection:	January 6, 1981

Assessment of General Condition of Dam

Based on visual inspection, past operational performance and Phase I engineering analyses, Crystal Lake Dam is assessed as being in good overall condition.

Based on investigations of the downstream flood plain made in connection with this report, it is recommended that the hazard potential classification be downgraded from high to significant hazard.

The spillway is capable of passing the designated spillway design flood (100-year storm) without an overtopping of the dam and, therefore, is assessed as being adequate.

The owner should, in the near future, develop an emergency action plan together with an effective warning system outlining actions to be taken by the operator to minimize downstream effects of an emergency at the dam.

In addition, it is recommended that the following remedial measures be undertaken by the owner in the near future.

1) The outlet works should be investigated with respect to operational adequacy and, if necessary, restored to proper operational condition.

2) Rusted CMP surface drain pipe should be replaced by proper inlet and pipe.
3) Erosion of the embankment adjacent to the upstream wingwalls of the bridge should be properly stabilized.
4) Deteriorating riprap on the upstream and downstream faces of embankment should be repaired where necessary.
5) All trees and adverse vegetation on the embankment should be removed.

In the future, the owner of the dam should develop written operating procedures and a periodic maintenance plan to ensure the safety of the dam.

Richard J. McDermott, P.E.

John E. Gribbin, P.E.

OVERVIEW - CRYSTAL LAKE DAM

31 JANUARY 1981

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PREFACE

This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams, for Phase I Investigations. Copies of these guidelines may be obtained from the Office of Chief of Engineers, Washington, D.C. 20314. The purpose of a Phase I Investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigation, and analyses involving topographic mapping, subsurface investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify any need for such studies.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team. It is important to note that the condition of dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can there be any chance that the unsafe conditions be detected.

Phase I inspections are not intended to provide detailed hydraulic and hydrologic analyses. In accordance with the established Guidelines, the Spillway Test flood is based on the estimated "Probable Maximum Flood" for the region (greatest reasonably possible storm runoff), or fractions thereof. The test flood provides a measure of relative spillway capacity and serves as an aid in determining the need for more detailed hydraulic and hydrologic studies, considering the size of the dam, its general condition and the downstream damage potential.

PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

CRYSTAL LAKE DAM, I.D. NJ00299

SECTION 1: PROJECT INFORMATION

1.1 General

a. Authority

Public Law 92-367, August 8, 1972, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a National Program of Dam Inspections throughout the United States. The Division of Water Resources of the New Jersey Department of Environmental Protection (NJDEP) in cooperation with the Philadelphia District of the Corps of Engineers has been assigned the responsibility of supervising the inspection of dams within the State of New Jersey. Storch Engineers has been retained by the NJDEP to inspect and report on a selected group of these dams. The NJDEP is under agreement with the Philadelphia District of the Corps of Engineers.

b. Purpose of Inspection

The visual inspection of Crystal Lake Dam was made on January 6, 1981. The purpose of the inspection was to make a general assessment of the structural integrity and operational adequacy of the dam structure and its appurtenances.

1.2 Description of Project

a. Description

The dam consists of an earth embankment supporting N.J. Highway Route 130. The spillway structure consists of a horseshoe-shaped concrete and steel interlocking sheet pile weir located on the upstream side of the embankment. At the center of the embankment a concrete bridge forms the spillway discharge channel.

The outlet works consists of a gated 2' x 2' sluice which transversely penetrates the center of the concrete spillway structure.

The crest of the dam is stabilized by the paved roadway of Route 130 and a heavy stand of grass. Portions of the upstream and downstream sides of the embankment near the bridge are stabilized by concrete and bituminous pavement.

The elevation of the spillway crest is 5.7, National Geodetic Vertical Datum (N.G.V.D.) while that of the crest of dam is 13.2. The elevation of the invert of the outlet works is 2.7 while that of the channel bed is 0.3. The overall length of the dam is 500 feet and its height is 12.9 feet. The top width of the dam is 75 feet and the side slopes are 2 horizontal to 1 vertical.

b. Location

Crystal Lake Dam is located in the Townships of Bordentown and Mansfield, Burlington County, New Jersey. It impounds a recreational lake located adjacent to Route 130. Principal access to the dam is Route 130 which traverses the crest. Discharge from the spillway of the dam flows into a tributary of the Delaware River.

c. Size and Hazard Classification

The dam is classified in accordance with criteria presented in "Recommended Guidelines for Safety Inspection of Dams" published by the U.S. Army Corps of Engineers. Size categories consist of Small, Intermediate and Large while hazard categories are designated as Low, Significant and High.

Size Classification: Crystal Lake Dam is classified as "Small" size since its maximum storage volume is 441 acre-feet (which is less than 1000 acre-feet) and its height is 12.9 feet (which is less than 40 feet).

Hazard Classification: Visual inspection of the downstream flood plain of the dam indicates that failure of the dam could damage the roadway of NJ Route 130 which traverses the crest of the embankment and the railroad embankment located 200 feet from the dam. However, the size of embankment and anticipated high tailwater during a storm equivalent to the SDF reduces the probability of a breach. Accordingly, Crystal Lake Dam is classified as "Significant" hazard.

d. Ownership

Crystal Lake Dam is owned and operated by the State of New Jersey, Department of Transportation, 1035 Parkway Avenue, Trenton, N.J. 08625. The impoundment, Crystal Lake, is owned by the Realty Transfer Co., 1 Elizabeth Plaza, Elizabeth, N.J. 07207.

e. Purpose of Dam

The purpose of the dam is the impoundment of a private recreational lake facility.

f. Design and Construction History

Reportedly, the present concrete horseshoe spillway structure at Crystal Lake Dam was constructed around 1940, replacing the old timber stoplog spillway. This spillway modification was initiated because of the flood of August 23, 1938 which overtopped the road embankment. The work was accomplished by the New Jersey State Highway Department.

Reportedly, no records or plans for the construction of the original dam are on file.

Dam Application No. 337 was issued to the New Jersey State Highway Department by the State Water Policy Commission on October 18, 1939 for the construction of a new spillway.

g. Normal Operational Procedures

The dam and appurtenances are maintained by the New Jersey Department of Transportation Maintenance Division. There is no fixed schedulc of maintenance; repairs are made as the need arises.

The outlet works has been used to drain the lake for lake maintenance purposes, usually on request from the owner of the impoundment. It is not known when the lake was last lowered.

1.3 Pertinent Data

a.	Drainage area	3.81 square miles
b.	Discharge at Damsite	
	Maximum flood at damsite	July 23, 1938 (Roadway overtopped) Inflow quantity unknown.

Outlet works at pool elevation	20 c.f.s.
Spillway capacity at top of dam	1350 c.f.s.

c. Elevation (N.G.V.D.)

Top of Dam	13.2
Maximum pool-design surcharge	13.2
Recreation pool	5.7
Spillway crest	5.7
Stream bed at centerline of dam	0.3
Maximum tailwater	15 (Estimated) (Normal tailwater varies with tidal fluctuations.)

d. Reservoir

Length of maximum pool	4000 feet (Estimated)
Length of recreation pool	2400 feet (Scaled)

e. Storage (Acre-feet)

Recreation pool	50
Design surcharge	441
Top of dam	441

f. Reservoir Surface (acres)

Top of dam	78.3 (Estimated)
Maximum Pool Design - design surcharge	90.0 (Estimated)
Recreation Pool	27.6

g. Dam

Type	Earthfill
Length	500 feet

Height	12.9 feet
Sideslopes - Upstream	2 horiz. to 1 vert.
- Downstream	2 horiz. to 1 vert.
Zoning	Unknown
Impervious core	Unknown
Cutoff	Unknown
Grout curtain	Unknown

h. Diversion and Regulating Tunnel — N.A.

i. Spillway

Type	Concrete Weir
Length of weir	36.0 feet
Crest elevation	5.7
Gates	N.A.
Upstream channel	N.A.
Downstream channel	12.5' x 8.8' Bridge Opening

j. Regulating Outlet

2' x 2' low-level outlet sluice controlled by slide gate

SECTION 2: ENGINEERING DATA

2.1 Design

No plans or calculations pertaining to the original construction of the dam could be obtained. Drawings and calcuations prepared in or about 1938 relating to the construction of the present spillway structure which shown plans of the spillway and appurtenant structures are available in the files of the NJDEP, Division of Water Resources.

Design flood peak flow was computed to be 783 c.f.s. based on the Central Jersey Curve. Hydraulic analysis indicated that the spillway and bridge could pass 894 c.f.s. with a free board of 2 feet.

2.2 Construction

No data or reports pertaining to the original construction of the dam are available. Construction data or reports are limited to a final acceptance report, dated June 24, 1944 for the construction of the present spillway structure.

2.3 Operation

Reportedly, informal maintenance reports are on file with the NJDOT Maintenance Division pertaining to spillway and bridge. No data pertaining to operations are available.

2.4 Evaluation

a. Availability

Available engineering data is limited to that which is on file with the NJDEP and NJDOT. These files contain plans and calculations relating to the present spillway structure and appurtenances.

b. Adequacy

Available engineering data pertaining to Crystal Lake Dam is of limited assistance to the performance of a Phase I evaluation. A list of absent information is included in paragraph 7.1.b.

c. Validity

The available hydraulic analyses appear to be valid with respect to engineering practice generally accepted in 1938. However, they are not valid according to analytic procedures developed by the Corps of Engineers for the present inspection and assessment program.

Although spillway discharge rates are in close agreement with values computed in connection with this Phase I Report, the design flood used in 1938 is not in conformance with the presently utilized SDF.

SECTION 3: VISUAL INSPECTION

3.1 Findings

a. General

The inspection of Crystal Lake Dam was performed on January 8, 1981 by staff members of Storch Engineers. A copy of the visual inspection check list is contained in Appendix 1. The following procedures were employed for the inspection:

1) The embankment of the dam, appurtenant structures and adjacent areas were examined.
2) The embankment and accessible appurtenant structures were measured and key elevations determined by surveyor's level.
3) The embankment, appurtenant structures and adjacent areas were photographed.

b. Dam

The roadway pavement was in satisfactory condition and the grass growth in the median and shoulder areas was thick. Steel guide rails extending for the entire length of the dam on both sides of the roadway appeared to be in satisfactory condition.

The upstream face of the dam was slightly irregular and generally covered with weeds, bushes and trees ranging in caliper from 2 inches to 8 inches. The upstream side of the embankment adjacent to both wingwalls of the bridge structure was stabilized with asphalt which appeared to be in satisfactory condition, however, some erosion was observed just beyond the limit of the asphalt. In addition, there was evidence of some riprap on the upstream face of the dam, but it appeared to be inadequate.

The downstream face of the dam appeared to be more regularly graded than the upstream face, and was covered with weeds, some bare spots and many small trees that had been cut off approximately 1 foot above the ground line. The areas adjacent to both sides of the bridge were stabilized by concrete debris that appeared to have been hand placed as riprap. To the left and right of the riprap were two concrete flumes that stabilized the soil and allowed surface water to run off the roadway and into the downstream stilling basin. Some concrete riprap at the toe of the dam on the right side of the bridge appeared to be dislodged. The concrete debris forming the riprap appeared to have been grouted in place. On the left side of the bridge the pieces of concrete were not grouted but simply hand placed.

c. Appurtenant Structures

The spillway crest was in the shape of a broad crested weir and was formed by two parallel rows of interlocking steel sheet piling. The sheet piling appeared to be sound and in generally satisfactory condition. The sheet piling extended from within the embankment on the left side, around the horse-shoe to within the embankment on the right side. The concrete spillway discharges onto a concrete apron which joins the downstream channel formed by the bridge opening.

The concrete railings on both the upstream and downstream headwalls for the bridge appeared to be in satisfactory condition. The downstream wingwalls appeared to be generally sound with the top, or cap, of the right wingwall cracked and spalled at its downstream end. The left wingwall appeared to be in satisfactory condition.

The wingwalls and the concrete surfaces on the upstream end of the bridge appeared, generally, to be in satisfactory condition. There were a few hairline cracks with a small amount of exudation present on the upstream wingwalls and on the concrete surfaces of the bridge abutments.

Two corrugated metal pipes were observed protruding from the embankment immediately to the left of the spillway on the upstream side. The smaller of the two did not appear to have an observable intake end and could possible be a toe drain. The larger of the two was in poor condition, being significantly rusted with some of the surface rusted through and with no observable inlet structure on the road. An additional corrugated metal pipe was observed on the right side about 10 feet from the spillway and appeared to be in satisfactory condition.

The low level outlet sluice gate mechanism was not operated at the time of inspection and appeared rusty but intact.

d. Reservoir Area

The impoundment of the dam is 2400 feet long with a width varying from 300 feet to 600 feet. The lake shores are thickly wooded with shore slopes of approximately 40 percent on the left side and more moderate slopes of 5 percent to 10 percent on the right side.

e. Downstream Channel

The spillway discharges into a tributary of the Delaware River.

Approximately 200 feet downstream from the dam there is a railroad constructed on an embankment running approximately parallel to the dam. There is a bridge opening in the embankment through which the downstream channel flows. Between the dam and the railroad embankment there is a large pool forming a stilling basin for the dam. Beyond or downstream from the railroad embankment the downstream channel is a broad, sluggish stream, wooded along the banks with an industrial yard on its right side.

SECTION 4: OPERATIONAL PROCEDURES

4.1 Procedures

The level of water in Crystal Lake is regulated by discharge over the concrete spillway. Reportedly, the outlet works of the dam is not currently used to drain the lake or to augment the discharge capacity of the spillway. It is not known when the lake was last drawn down.

The tailwater elevation normally varies in accordance with tidal fluctuations.

4.2 Maintenance of the Dam

Reportedly, maintenance is performed on an "as needed" basis. The NJDOT Maintenance Department maintains the shoulder of the roadway on the crest of the dam and reportedly does not maintain the upstream or downstream embankments of the dam.

4.3 Maintenance of Operating Facilities

It is not known if the operating mechanism for the outlet works currently functions properly. Reportedly, the outlet is not currently maintained.

4.4. Description of Warning System

Reportedly, no warning system is currently in use for the dam.

4.5 Evaluation of Operational Adequacy

The operation of the dam has been successful to the extent that the dam reportedly has not been overtopped since the construction of the new spillway in 1940. Reportedly, the dam (roadway) was overtopped during the flood of July 23, 1938.

Although maintenance has been adequate in some areas, some aspects of dam maintenance have not been satisfactorily performed, including the following:

1) Outlet works facilities not maintained.
2) Spalled concrete and cracks on wingwalls not repaired.
3) Trees on upstream face of embankment not removed.
4) Eroded areas adjacent to upstream end of bridge not stabilized.
5) Deteriorated pipes protruding from upstream face not repaired or replaced.
6) Dislodged concrete riprap on upstream face not replaced.

SECTION 5: HYDRAULIC/HYDROLOGIC

5.1 Evaluation of Features

a. Design Data

The quantity of storm water runoff that the spillway should be able to handle is based on the size and hazard classification of the dam. This runoff quantity called the spillway design flood (SDF) is described in terms of return frequency or probable maximum flood (PMF) depending on the extent of the dam's size and potential hazard. According to the "Recommended Guidelines for Safety Inspection of Dams" published by the U.S. Army Corps of Engineers, the SDF for Crystal Lake Dam falls in a range of 100-year frequency to 1/2 PMF. In this case, the low end of the range, 100-year frequency is chosen since the factors used to select size and hazard classification are on the low side of their respective ranges.

The SDF peak computed for Crystal Lake Dam is 2613 c.f.s. This value is derived from the PMF flood hydrograph computed by the use of the HEC-1-DAM Flood Hydrograph Computer Program using the Soil Conservation Service triangular unit hydrograph with curvilinear transformation. Hydrologic computations and computer output are contained in Appendix 4.

The spillway discharge rates were computed by the use of a weir formula appropriate for the configuration of the spillway structure. The total spillway discharge with lake level equal to the top of the dam was computed to be 1350 c.f.s. The SDF was routed through the dam by use of the HEC-1-DAM computer program using the modified Puls Method. In routing the SDF, it was found that the dam crest would not be overtopped with 0.2 foot of freeboard remaining. Accordingly, the subject spillway is assessed as being adequate in accordance with criteria developed by the U.S. Army Corps of Engineers.

b. Experience Data

Reportedly, the dam has not been overtopped since its new spillway construction in 1940, but was overtopped during the flood of July 23, 1938.

Also, Condition 10 of the permit to reconstruct the spillway, issued in 1939, stated: "Applicant recognizes that spillway will be drowned out by larger floods in Delaware River."

c. Visual Observation

No evidence was found at the time of inspection that would indicate that the dam had been overtopped.

d. Overtopping Potential

According to the hydraulic and hydrologic analyses, a storm of intensity equivalent to the SDF will pass through the spillway with a minimum freeboard of 0.2 foot.

e. Drawdown Data

Drawdown of the lake is accomplished by opening the low level sluice gate. Total time for drawdown is estimated to be 28 hours. (See Appendix 4.) However, the amount of drawdown depends on tidal influenced fluctuations of the tailwater.

SECTION 6: STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability

a. Visual Observations

The dam appeared, at the time of inspection to be outwardly structurally sound with no evidence of embankment cracks or distress. The erosion that was observed near the upstream wingwall on the left side of the spillway and the hairline cracks observed in the bridge structure does not appear to be an indication of distress in the dam.

b. Generalized Soils Description

The generalized soils description of the site consists of a discontinuous mantle of unconsolidated, stratified alluvial deposits, composed of silty sand and gravel overlying stratified deposits mostly of marine origin. The marine deposits are composed of clay with varying amounts of silt and sand. Depth to bedrock is greater than 100 feet.

c. Design and Construction Data

Analysis of structural stability and construction data for the embankment are not available.

d. Operating Records

No operating records are available for the dam. The water level of Crystal Lake is not monitored.

e. Post-Construction Changes

Reportedly, post-construction changes have been limited to the construction of the new spillway and outlet works in 1940 which are on file with the NJDEP and NJDOT.

f. Seismic Stability

Crystal Lake Dam is located in Seismic Zone 1 as defined in "Recommended Guidelines for Safety Inspection of Dams" which is a zone of very low seismic activity. Experience indicates that dams in Seismic Zone 1 will have adequate stability under seismic loading conditions if they have adequate stability under static loading conditions. Crystal Lake Dam appeared to be stable at the time of inspection.

SECTION 7: ASSESSMENT AND RECOMMENDATIONS

7.1 Dam Assessment

a. Safety

Based on hydraulic and hydrologic analyses outlined in Section 5 and Appendix 4, the spillway of Crystal Lake Dam is assessed as being adequate. The spillway is able to pass the SDF without an overtopping of the dam.

The embankment appeared, at the time of inspection, to be generally outwardly stable. Observed minor erosion and hairline cracks in the bridge structure are not considered evidence of dam instability.

b. Adequacy of Information

Information sources for this report include 1) field inspections, 2) USGS quadrangle, 3) consultation with personnel of the Realty Transfer Company and 4) consultation and information on file with the NJDEP and NJDOT. The information obtained is sufficient to allow a Phase I assessment as outlined in "Recommended Guidelines for Safety Inspection of Dams."

Some of the absent data are as follows:

1. Description of fill material for embankment.
2. Soils report for the site.
3. Design report.

c. Necessity for Additional Data/Evaluation

Although some data pertaining to Crystal Lake Dam are not available, additional data are not considered imperative for this Phase I evaluation.

7.2 Recommendations

a. Remedial Measures

Based on hydraulic and hydrologic analyses outlined in paragraph 5.1.a, the spillway is considered to be adequate.

The owner should, in the near future, develop an emergency action plan together with an effective warning system outlining actions to be taken by the operator to minimize downstream effects of an emergency at the dam.

In addition, it is recommended that the following remedial measures be undertaken by the owner in the near future.

1) The outlet works should be investigated with respect to operational adequacy and, if necessary, restored to proper operational condition.
2) Rusted CMP surface drain pipe should be replaced by proper inlet and pipe.
3) Erosion of the embankment adjacent to the upstream wingwalls of the bridge should be properly stabilized.
4) Deteriorating riprap on the upstream and downstream faces of embankment should be repaired where necessary.
5) All trees and adverse vegetation on the embankment should be removed.

b. Maintenance

In the future, the owner of the dam should develop written operating procedures and a periodic maintenance plan to ensure the safety of the dam.

PLATES

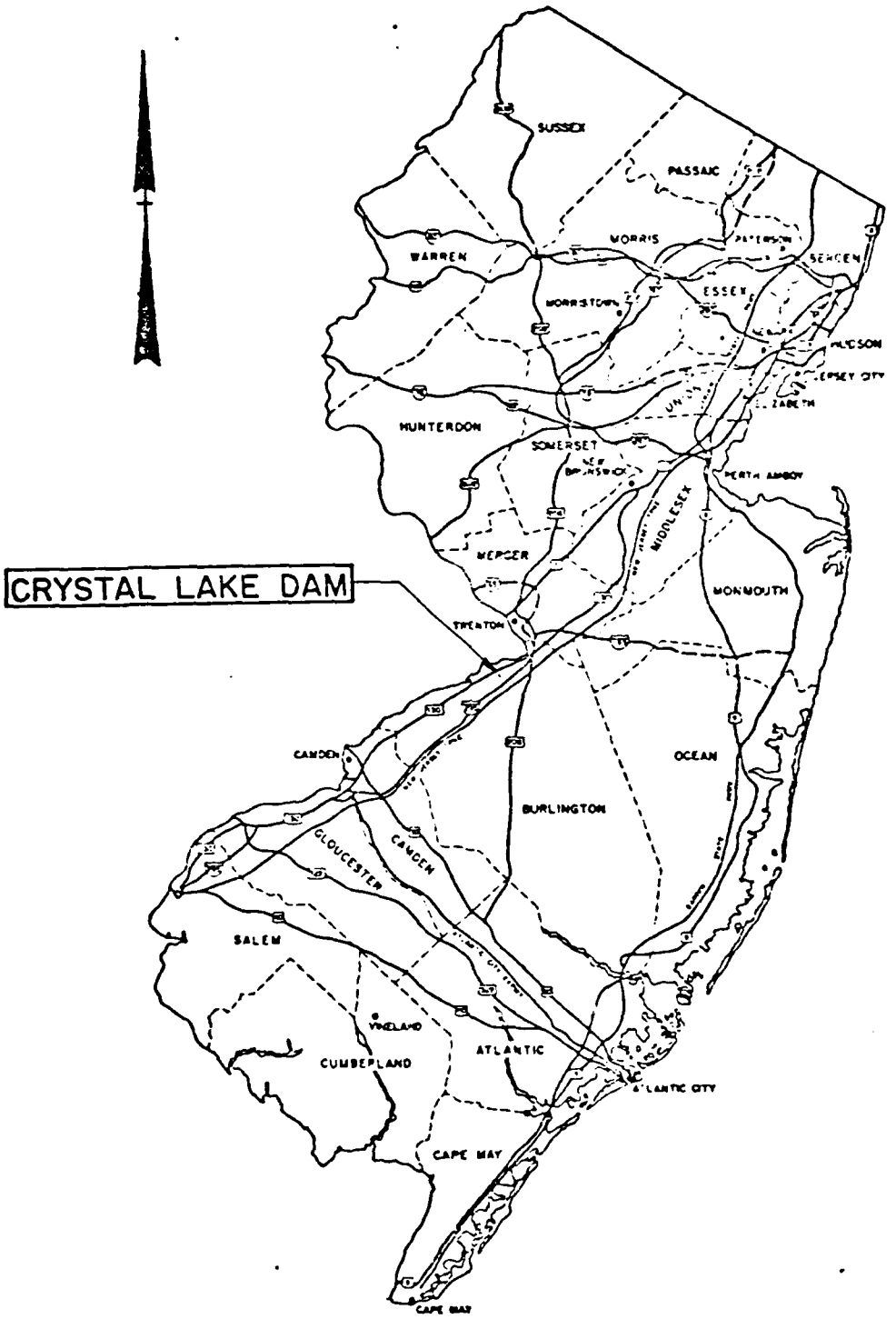
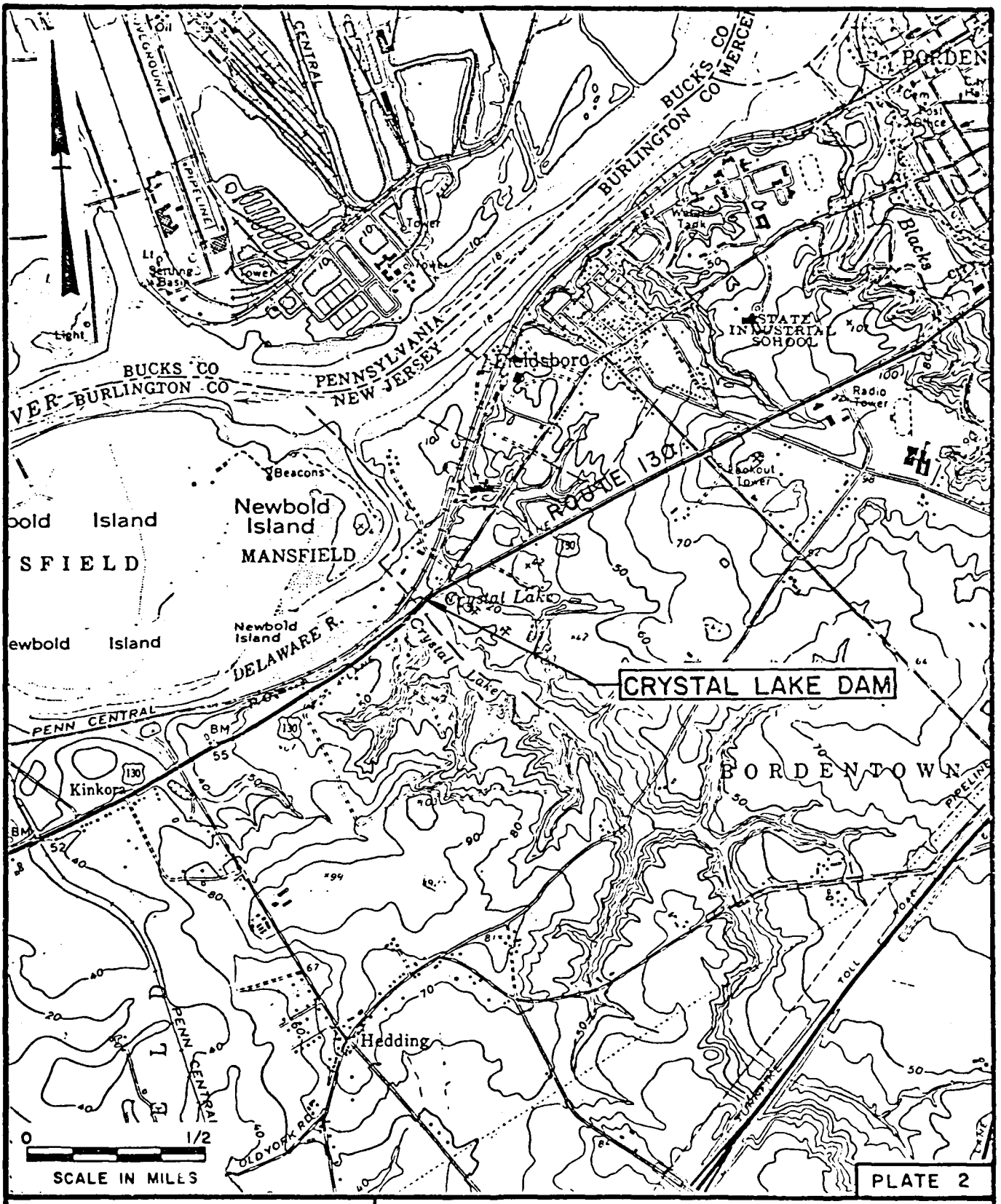


PLATE 1

STORCH ENGINEERS FLORHAM PARK, NEW JERSEY	INSPECTION AND EVALUATION OF DAMS KEY MAP CRYSTAL LAKE DAM
DIVISION OF WATER RESOURCES N.J. DEPT. OF ENVIR. PROTECTION TRENTON, NEW JERSEY	SCALE: NONE DATE: FEB 1981



STORCH ENGINEERS
FLORHAM PARK, NEW JERSEY

DIVISION OF WATER RESOURCES
N.J. DEPT. OF ENVIR. PROTECTION
TRENTON, NEW JERSEY

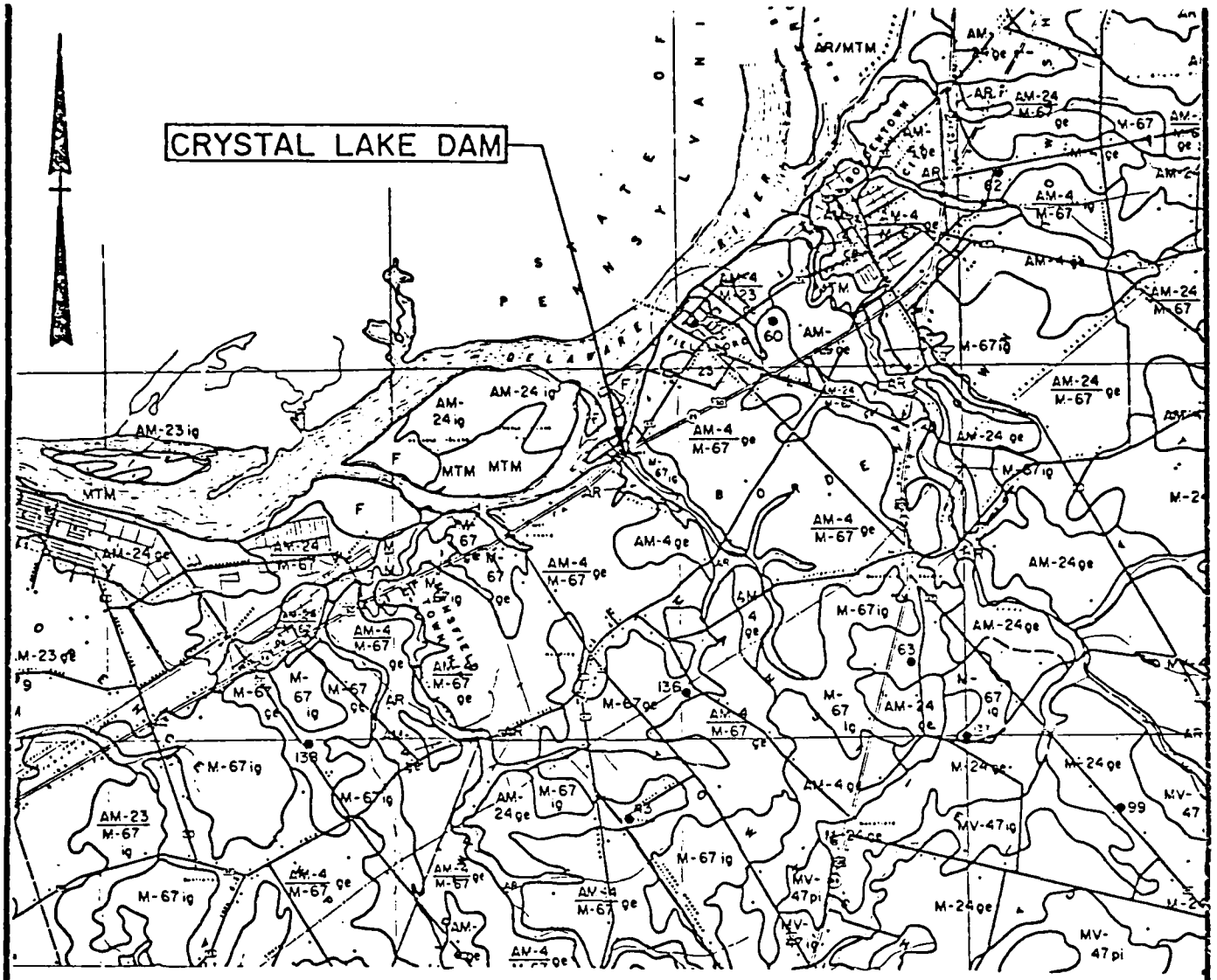
INSPECTION AND EVALUATION OF DAMS

VICINITY MAP

CRYSTAL LAKE DAM

SCALE: AS SHOWN

DATE: FEB. 1981



Legend

AR	Recent alluvium deposited adjacent to present stream courses.
AM-4	Unconsolidated stratified alluvial material
M-67	Stratified deposits of marine origin

Note: Information taken from Rutgers University, Soil Survey of New Jersey, Report No. 20, Burlington County, May 1955 and Geologic Map of New Jersey prepared by J.V. Lewis and H. Kummel 1910-1912, revised by H.B. Kummel 1931 and M. Johnson 1950.

PLATE 3

STORCH ENGINEERS
FLORHAM PARK, NEW JERSEY.

DIVISION OF WATER RESOURCES
N.J. DEPT. OF ENVIR. PROTECTION
TRENTON, NEW JERSEY.

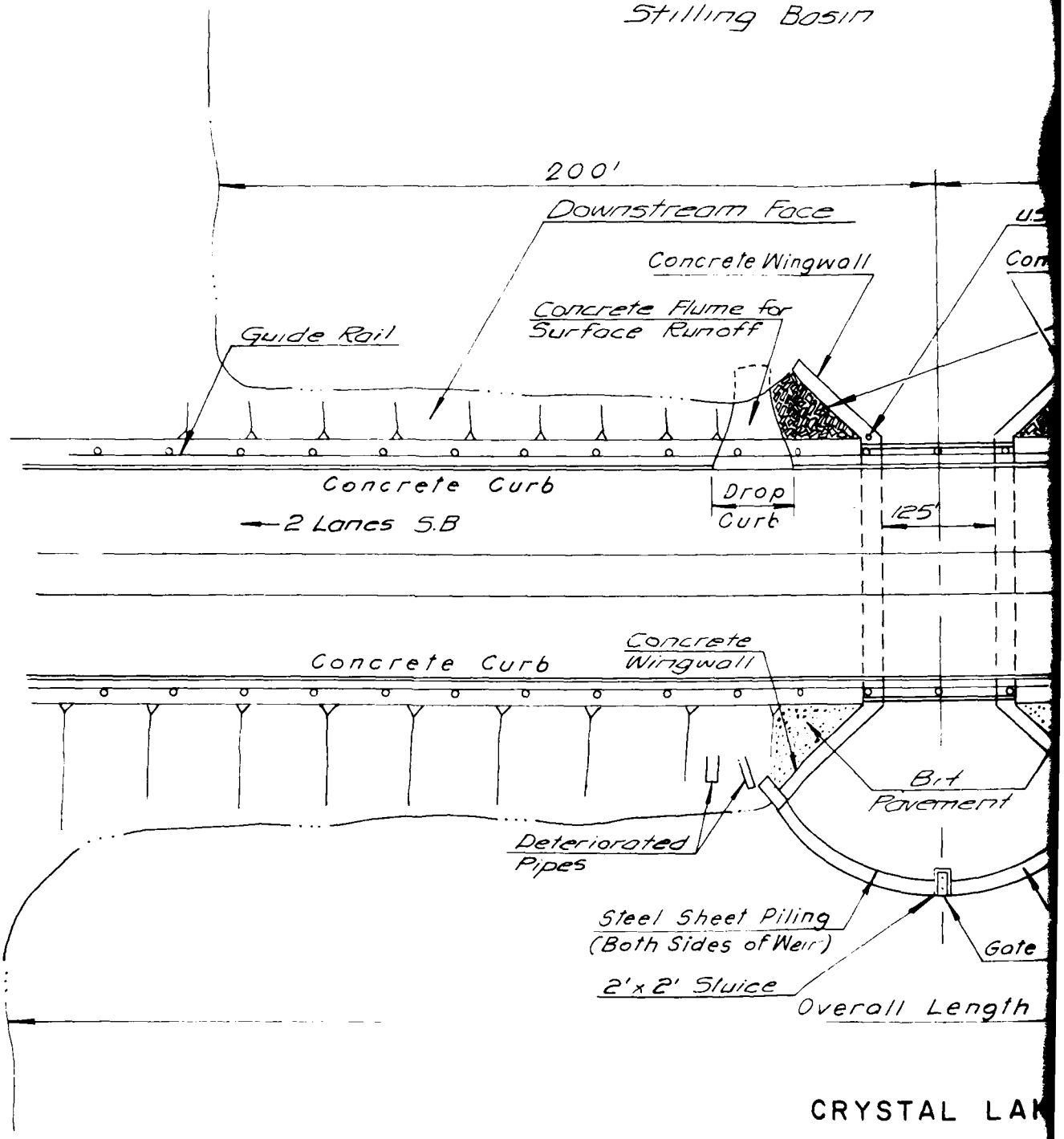
INSPECTION AND EVALUATION OF DAMS

SOIL MAP

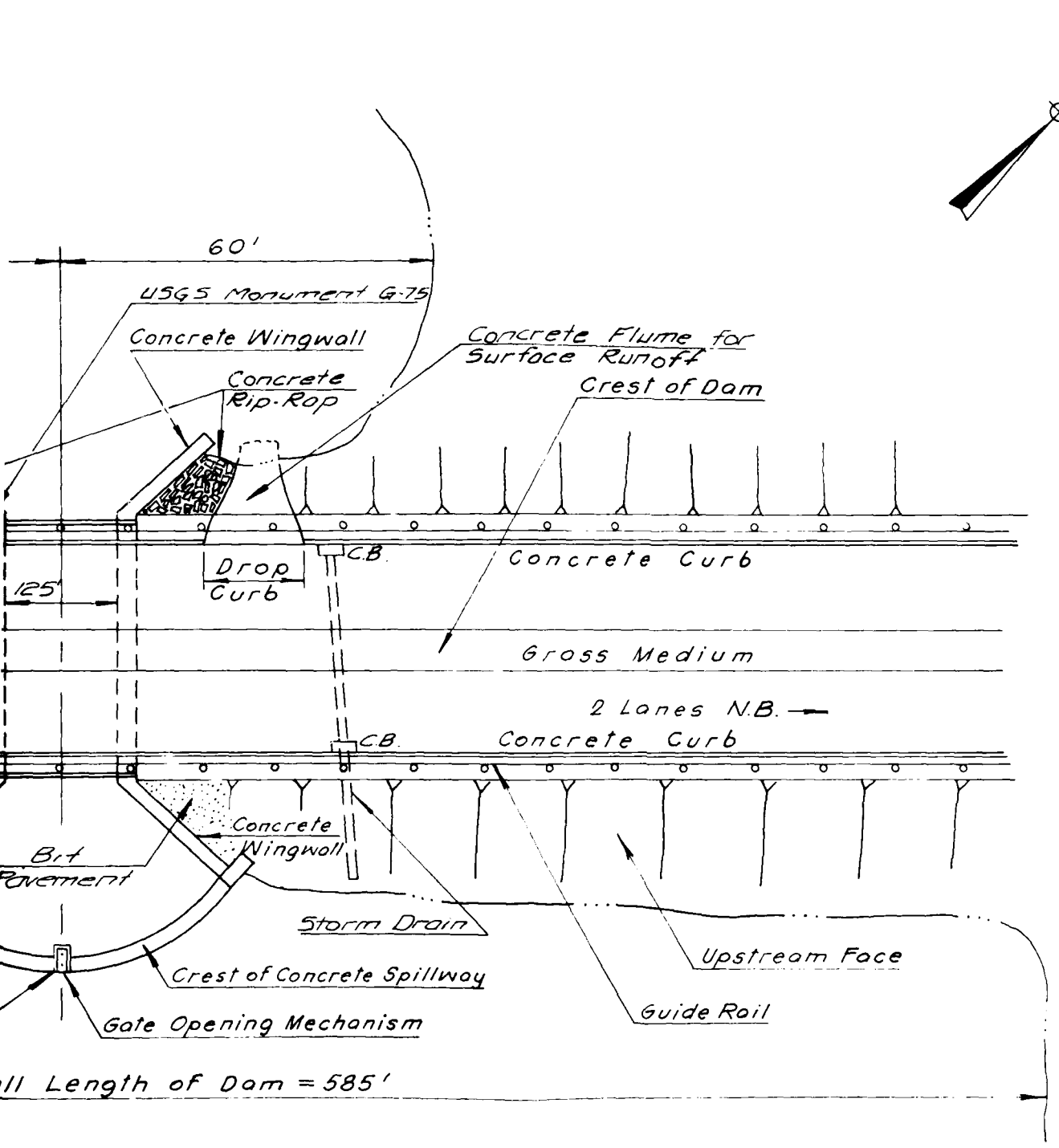
CRYSTAL LAKE DAM

SCALE: NONE

DATE: FEB. 1981



Note Information taken from field Inspection January 6, 1981



STAL LAKE

PLATE 4

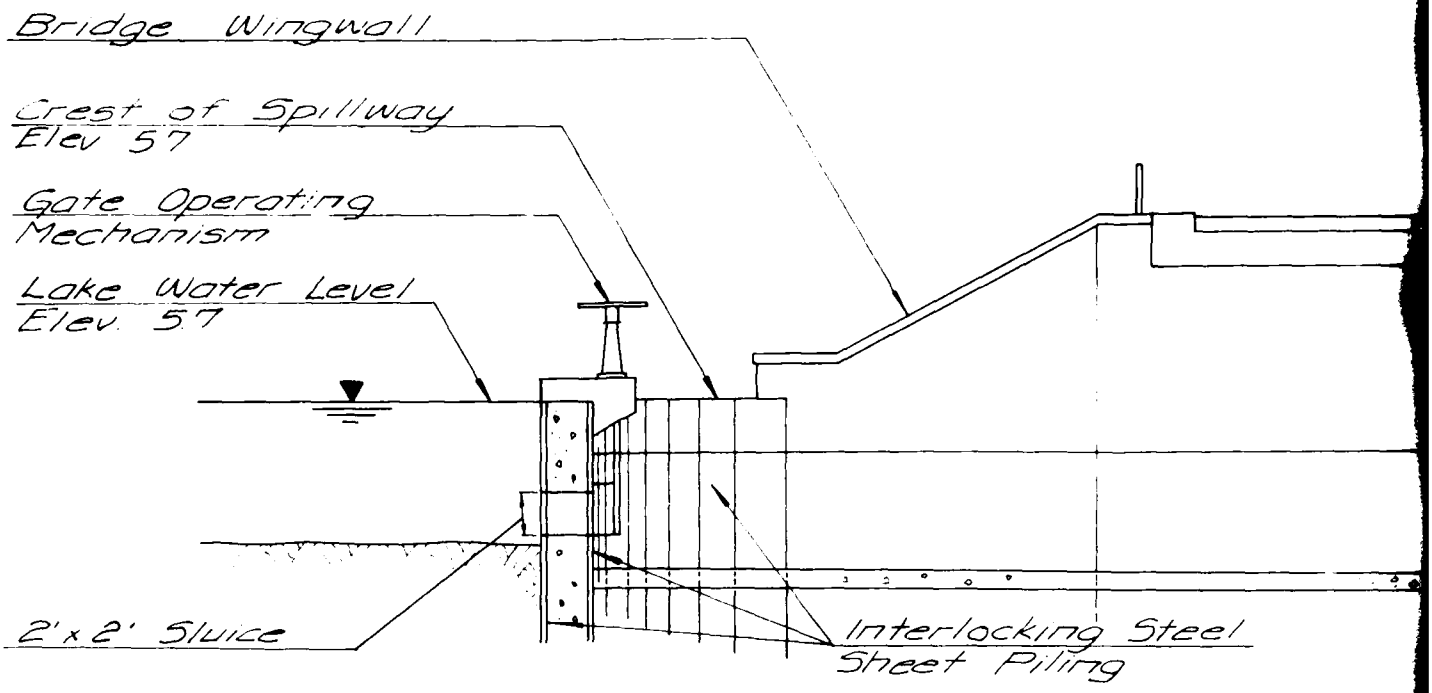
STORCH ENGINEERS FLORHAM PARK, NEW JERSEY	DIVISION OF WATER RESOURCES N.J. DEPT. OF ENVIR. PROTECTION TRENTON, NEW JERSEY

INSPECTION AND EVALUATION OF DAMS

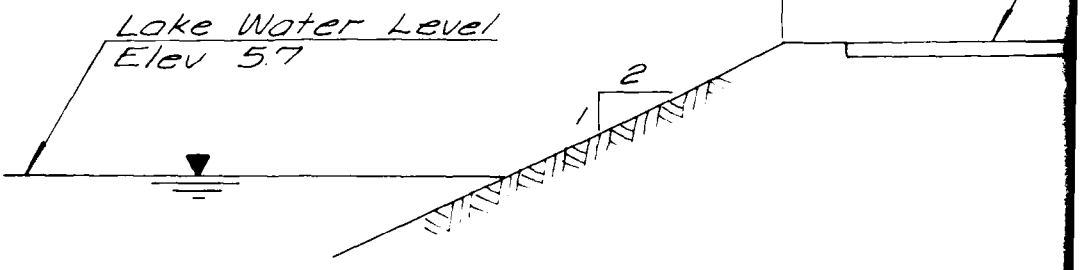
GENERAL PLAN

CRYSTAL LAKE DAM

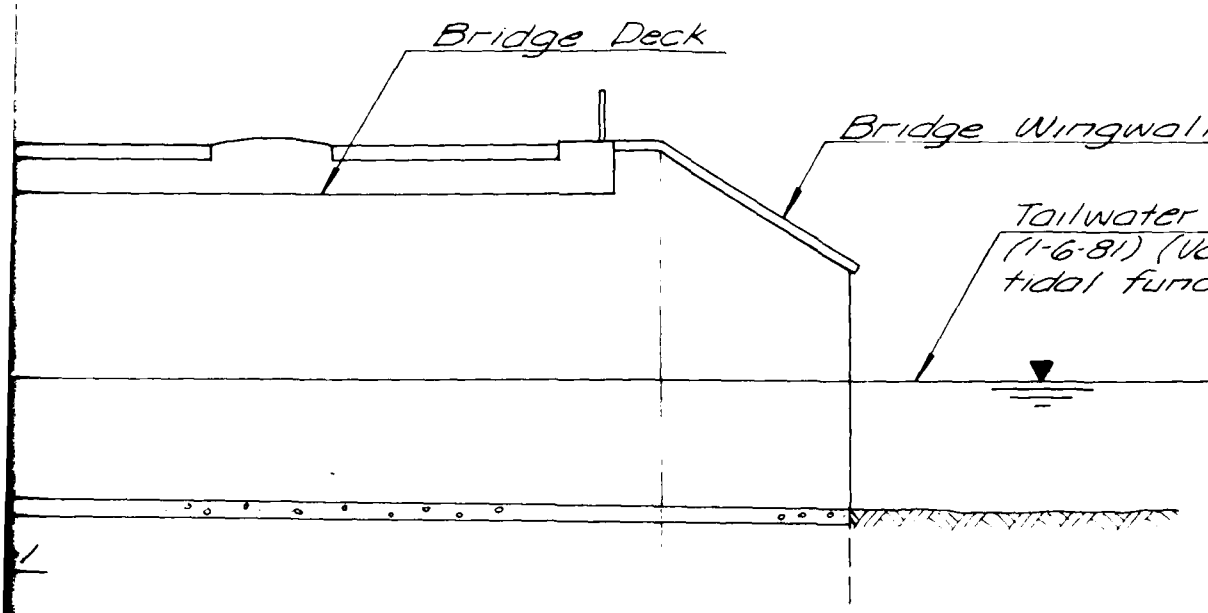
ID NJ 00299	SCALE: NOT TO SCALE
	DATE: FEB. 1981



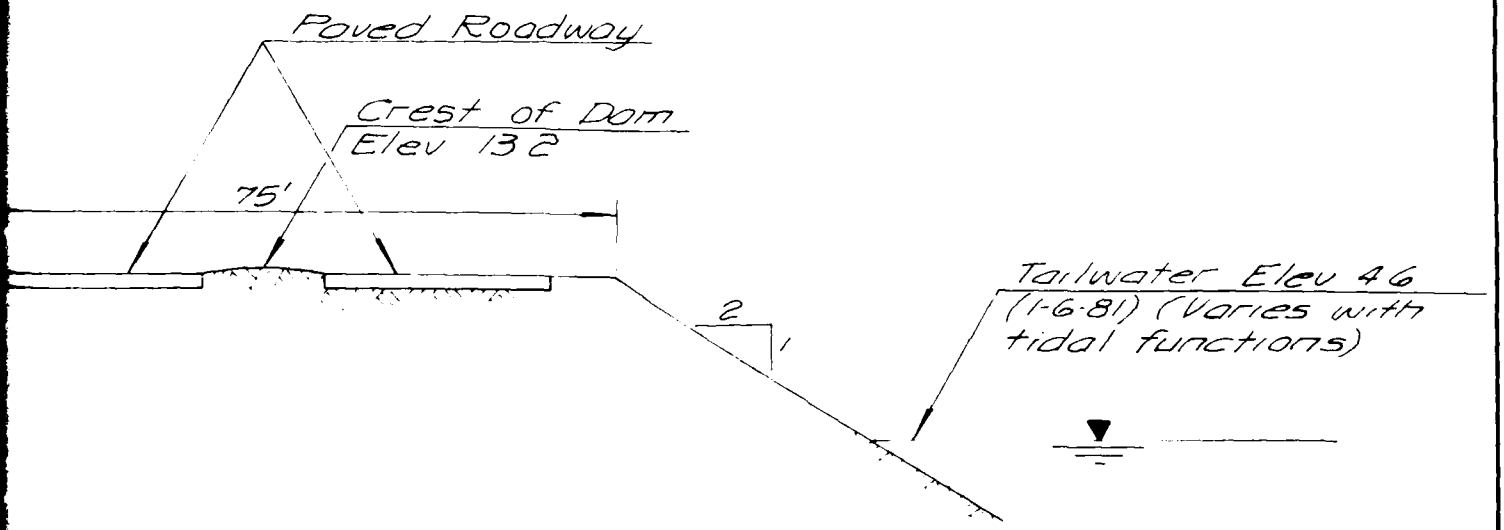
SPILLW



TYPIC



SPILLWAY SECTION



TYPICAL DAM SECTION

PLATE 5

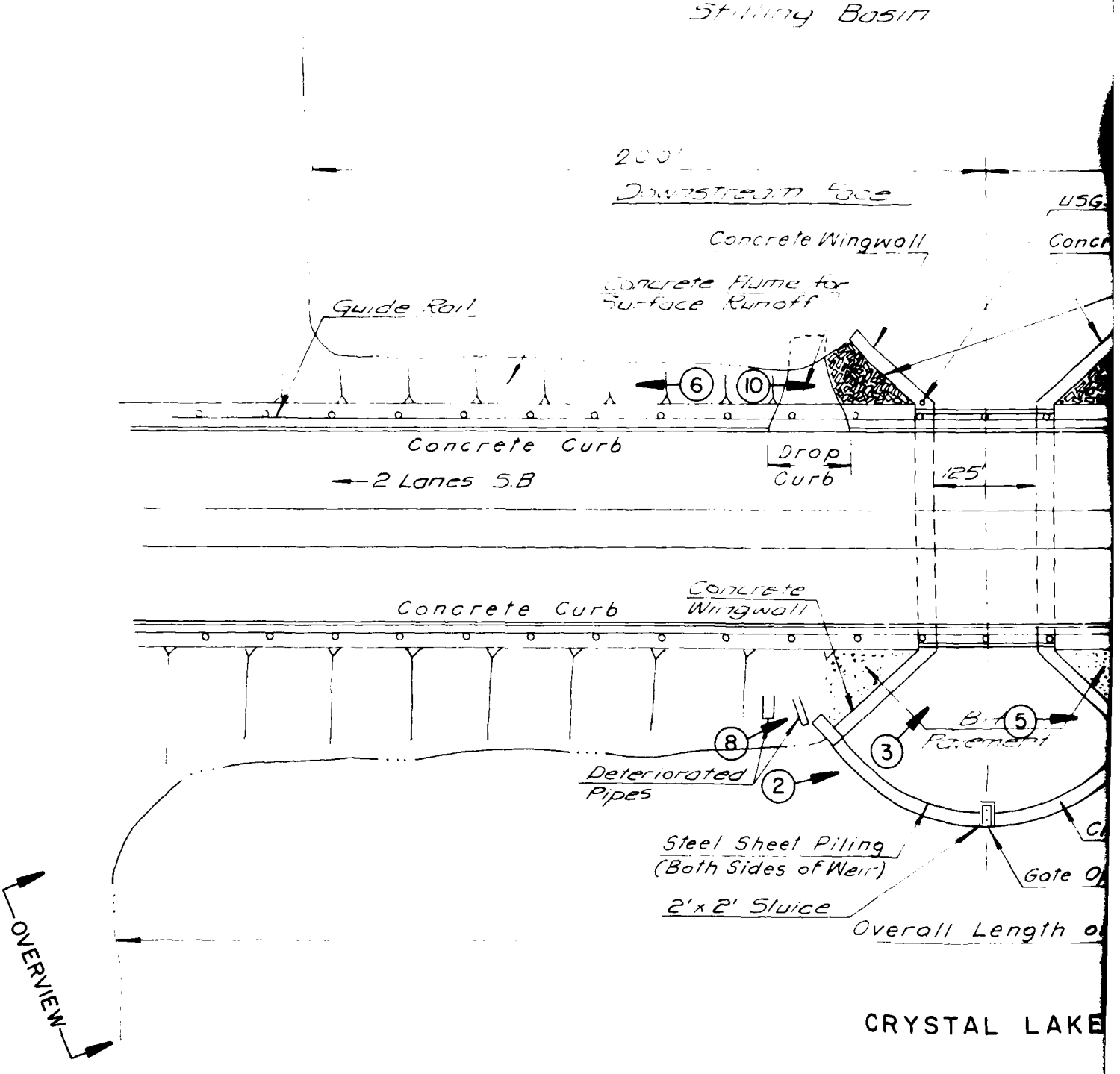
STORCH ENGINEERS FLORHAM PARK, NEW JERSEY	DIVISION OF WATER RESOURCES N.J. DEPT. OF ENVIR. PROTECTION TRENTON, NEW JERSEY

INSPECTION AND EVALUATION OF DAMS

SECTIONS

CRYSTAL LAKE DAM

I.D. N.J. 00299	SCALE: NOT TO SCALE
	DATE: FEB 1981



Note Information taken from field Inspection January 6, 1981

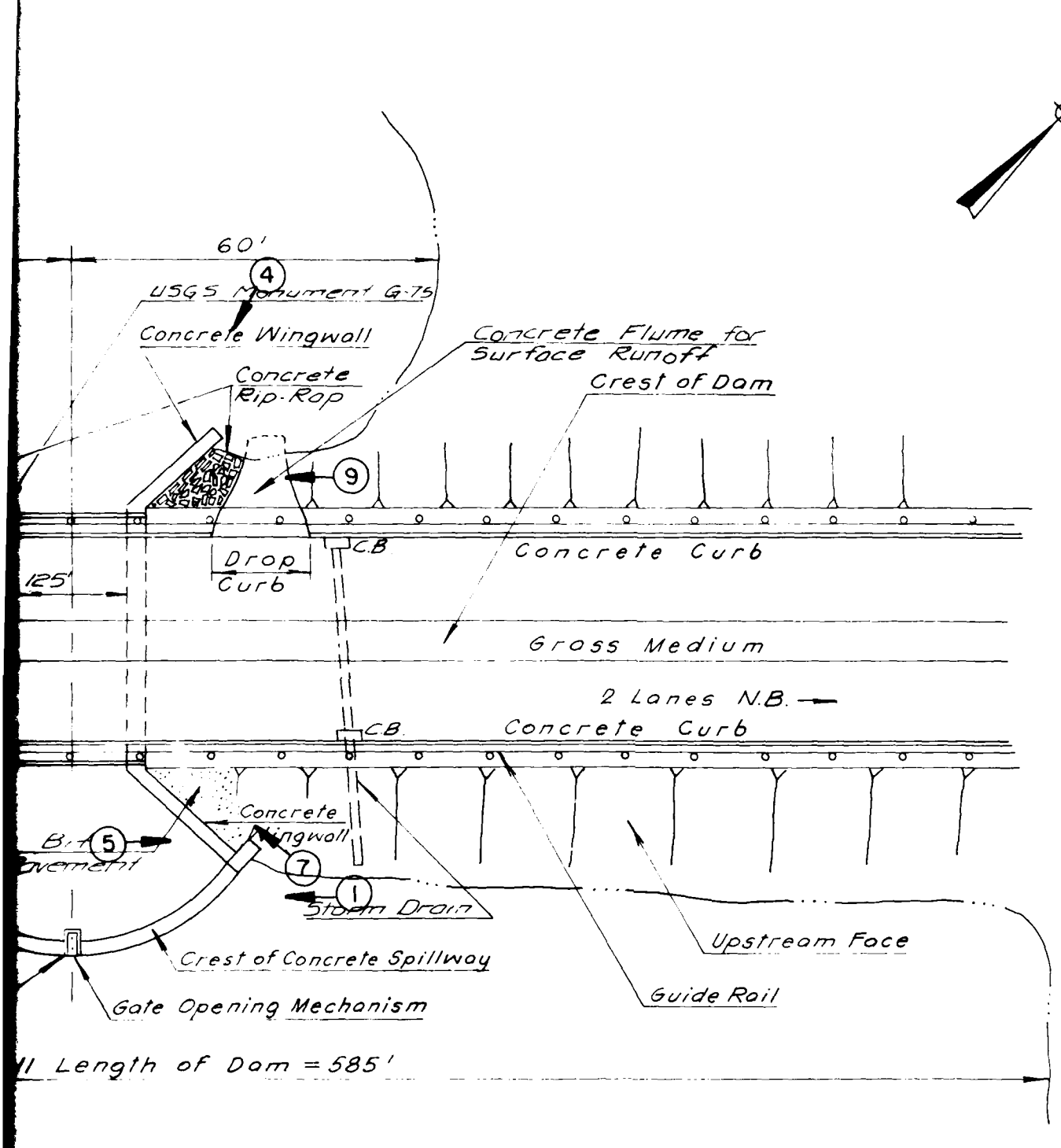


PLATE 6

TAL LAKE

STORCH ENGINEERS FLORHAM PARK, NEW JERSEY	DIVISION OF WATER RESOURCES N.J. DEPT. OF ENVIR. PROTECTION TRENTON, NEW JERSEY

INSPECTION AND EVALUATION OF DAMS

PHOTO LOCATION PLAN
CRYSTAL LAKE DAM

I.D N.J. 00299	SCALE: NOT TO SCALE
	DATE: FEB. 1981

APPENDIX 1

Check List - Visual Inspection

Check List - Engineering Data

Check List

Visual Inspection

Phase I

Name of Dam Crystal Lake Dam County Burlington State N.J. Coordinators NJDEP

Date(s) Inspection 1/6/81 Weather Cloudy Temperature 25°F

Pool Elevation at time of Inspection 5.7 M.S.L. Tailwater at Time of Inspection 4.6 M.S.L.

Inspection Personnel:

John Gribbin — Richard McDermott

Daniel Buckelew

Mark Brady

John Gribbin Recorder

EMBANKMENT

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
GENERAL	Paved highway on crest (Rt. 130) in satisfactory condition. Bushes, weeds and trees (2"-8") on upstream face. Trees on downstream face have been cut off approx. 1 foot from ground. Steel guide rails in good condition.	Trees should be removed.
JUNCTION OF EMBANKMENT AND ABUTMENT, SPILLWAY AND DAM	Junctions appear sound. Some surface erosion observed. See "Erosion" next sheet.	
ANY NOTICEABLE SEEPAGE	None observed.	
STAFF GAGE AND RECORDER	Noen observed.	
DRAINS	Inlets and pipes to convey surface runoff from road, in generally satisfactory condition. However, one CMP severely rusted.	Rusted CMP surface drain pipe should be replaced by proper inlet and pipe.

EMBANKMENT

VISUAL EXAMINATION	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SURFACE CRACKS	None observed.	
UNUSUAL MOVEMENT OR CRACKING AT OR BEYOND THE TOE	None observed.	
SLOUGHING OR EROSION OF EMBANKMENT AND ABUTMENT SLOPES	Upstream face slightly irregular in alignment; possibly due to wave erosion. Erosion from surface runoff observed adjacent to left, upstream wingwall of bridge.	Embankment stabilization adjacent to bridge should be renovated.
VERTICAL AND HORIZONTAL ALIGNMENT OF THE CREST	Vertical: generally level. Horizontal: downstream face aligned straight; upstream face slightly irregular.	
RIPRAP	Riprap on upstream face (12" stones) generally not adequate. Grouted riprap adjacent to right downstream wingwall of bridge generally adequate with some broken away at toe.	Upstream riprap should be renovated by adding more complete cover. Grouted riprap on downstream face should be renovated where required.

OUTLET WORKS

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONCRETE SURFACES IN OUTLET CONDUIT	Submerged--could not be observed.	
INTAKE STRUCTURE	Not observed	
OUTLET STRUCTURE	Not observed	
OUTLET CHANNEL	Outlet works discharges into spillway discharge channel.	
GATE AND GATE HOUSING	Gate not observed. Gate operating mechanism appeared rusty but intact. Mechanism not operated at time of inspection.	

SPILLWAY

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
WEIR	Concrete surface and steel sheet piles in generally satisfactory condition.	
INTAKE CHANNEL	N.A.	
DISCHARGE CHANNEL	Upstream wingwalls and abutments in satisfactory condition, with some hairline cracks observed. Downstream wingwalls generally sound; the cap of the right wingwall cracked and spalled at its downstream end.	Discharge channel formed by concrete bridge abutments and wingwalls.
BRIDGE	Bridge deck appeared to be in satisfactory condition.	Under side of deck not observed.

INSTRUMENTATION

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
MONUMENTATION/SURVEYS	USGS monument marked G75 observed on left downstream wingwall of bridge.	
OBSERVATION WELLS	None	
WEIRS	None	
PIEZOMETERS	None	
OTHER		

RESERVOIR

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SLOPES	The lake shores are thickly wooded with shore slopes of approx. 40% on the left side and more moderate slopes of approx. 5% to 10% on the right side.	
SEDIMENTATION	Unknown.	
STRUCTURES ALONG BANKS	None observed.	

DOWNSTREAM CHANNEL

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONDITION (OBSTRUCTION, DEBRIS, ETC.)	Large stilling basin immediately downstream from dam. Discharge from dam enters downstream channel through opening in railroad embankment located approx. 200 feet downstream from dam. Channel flows along railroad embankment approx. 1500 feet to Delaware River.	
SLOPES	Right bank generally flat with left bank formed by railroad embankment.	
STRUCTURES ALONG BANKS	Railroad tracks along left bank and industrial complex along right bank.	

CHECK LIST
ENGINEERING DATA
DESIGN, CONSTRUCTION, OPERATION

ITEM			REMARKS
DAM	-	PLAN	On file with N.J. DEP (Dam Permit #337)
		SECTIONS	
SPILLWAY	-	PLAN	On file with N.J. DEP and N.J. D.O.T. (Bridge File #0317-159)
		SECTIONS	
		DETAILS	
OPERATING EQUIPMENT PLANS & DETAILS			On file with N.J. DEP and N.J. D.O.T.
OUTLETS	-	PLAN	On file with N.J. DEP and N.J. D.O.T.
		DETAILS	
		CONSTRAINTS	
		DISCHARGE RATINGS	
HYDRAULIC/HYDROLOGIC DATA			On file with N.J.DEP
RAINFALL/RESERVOIR RECORDS			Not available
CONSTRUCTION HISTORY			On file with N.J. DEP
LOCATION MAP			On file with N.J. DEP and N.J.D.O.T.

ITEM	REMARKS
DESIGN REPORTS	Not available
GEOLOGY REPORTS	Not available
DESIGN COMPUTATIONS HYDROLOGY & HYDRAULICS DAM INSTABILITY SEEPAGE STUDIES	On file with NJDEP
MATERIALS INVESTIGATIONS BORING RECORDS LABORATORY FIELD	Not available
POST-CONSTRUCTION SURVEYS OF DAM	Not available
BORROW SOURCES	Not available

ITEM	REMARKS
MONITORING SYSTEMS	Not available
MODIFICATIONS	Spillway modification, on file with NJDEP
HIGH POOL RECORDS	Dam overtopped during flood of July 23, 1938 on file with NJDEP
POST CONSTRUCTION ENGINEERING STUDIES AND REPORTS	Not available
PRIOR ACCIDENTS OR FAILURE OF DAM DESCRIPTION REPORTS	Not available
MAINTENANCE OPERATION RECORDS	Informal reports on file with NJDOT

APPENDIX 2

Photographs

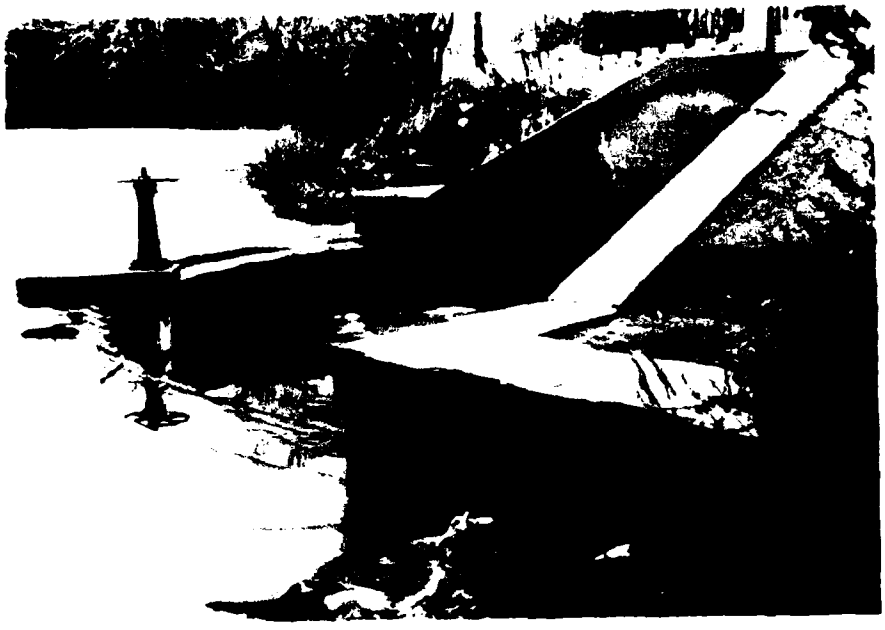


PHOTO 1

SPILLWAY - LOOKING FROM RIGHT

PHOTO 2

SPILLWAY - LOOKING FROM LEFT

CRYSTAL LAKE DAM
6 JANUARY 1981

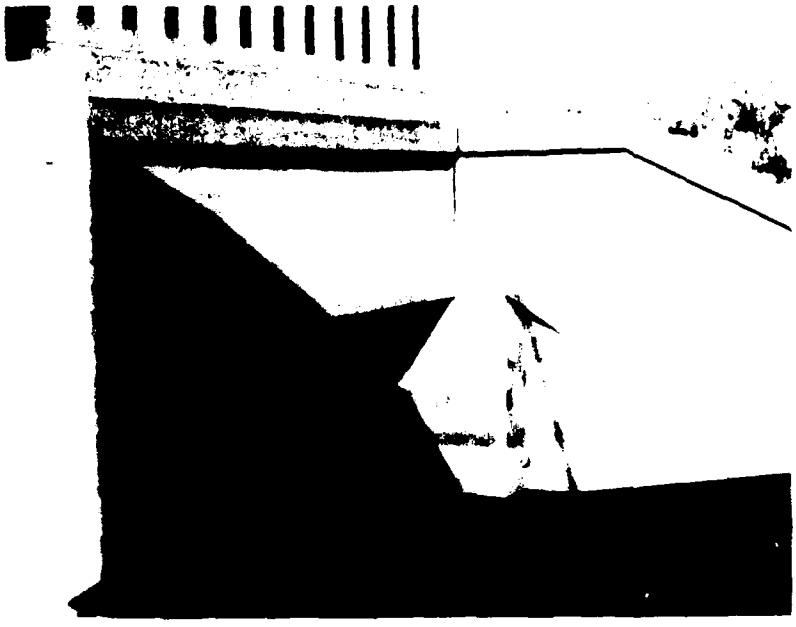


PHOTO 3

UPSTREAM END OF BRIDGE

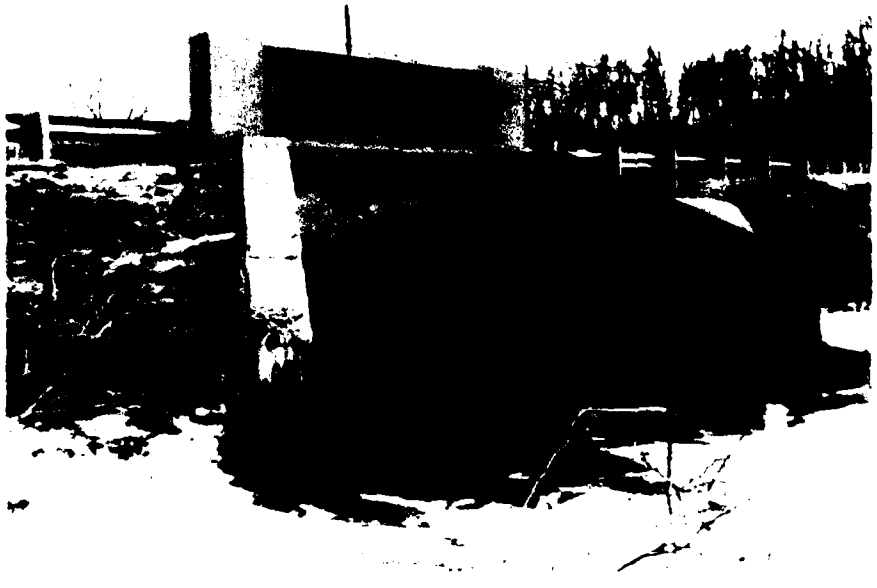


PHOTO 4

DOWNSTREAM END OF BRIDGE

CRYSTAL LAKE DAM
6 JANUARY 1981

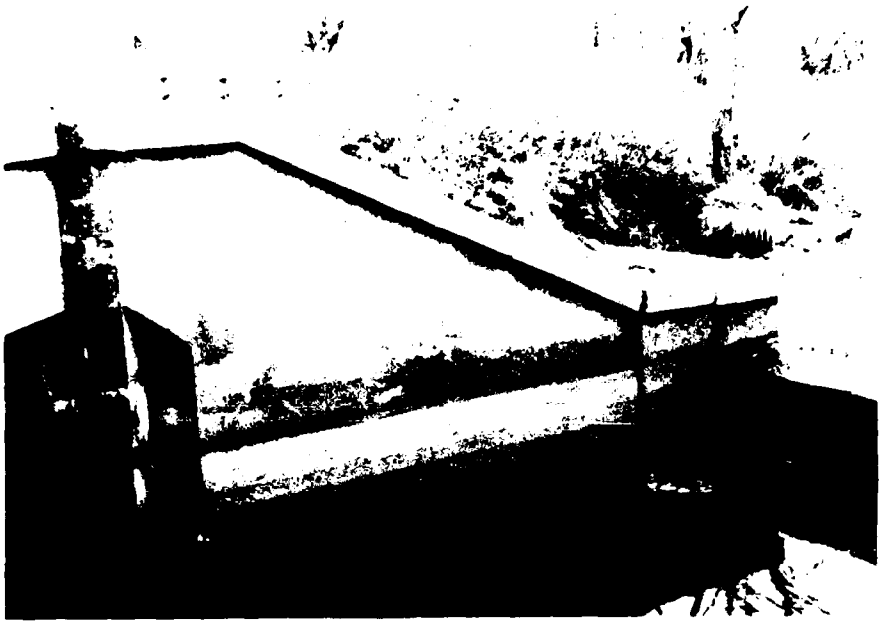


PHOTO 5

UPSTREAM FACE OF DAM

PHOTO 6

DOWNSTREAM FACE OF DAM

CRYSTAL LAKE DAM
6 JANUARY 1981

PHOTO 7

BITUMINOUS SLOPE PROTECTION ADJACENT
TO RIGHT, UPSTREAM END OF BRIDGE

PHOTO 8

BITUMINOUS SLOPE PROTECTION ADJACENT
TO LEFT, UPSTREAM END OF BRIDGE.
CORRUGATED METAL DRAINS IN FOREGROUND

CRYSTAL LAKE DAM
6 JANUARY1981

PHOTO 9

CONCRETE SLOPE PROTECTION ADJACENT
TO RIGHT, DOWNSTREAM END OF BRIDGE

PHOTO 10

CONCRETE SLOPE PROTECTION ADJACENT TO LEFT,
DOWNSTREAM END OF BRIDGE

APPENDIX 3

Engineering Data

CHECK LIST

HYDROLOGIC AND HYDRAULIC DATA

ENGINEERING DATA

DRAINAGE AREA CHARACTERISTICS: Farmland and Wooded

ELEVATION TOP NORMAL POOL (STORAGE CAPACITY): 5.70 (50 acre-feet)

ELEVATION TOP FLOOD CONTROL POOL (STORAGE CAPACITY): N/A

ELEVATION MAXIMUM DESIGN POOL: 13.2

ELEVATION TOP DAM: 13.2

SPILLWAY CREST: Uncontrolled Weir

a. Elevation 5.7

b. Type Broad Crested Weir (Horseshoe Shape)

c. Width 2.5 feet

d. Length 36.0 feet

e. Location Spillover Upstream Side of Dam

f. Number and Type of Gates N.A.

OUTLET WORKS: 2' x 2' Gated Sluice

a. Type Submerged Orifice

b. Location Center of Spillway Weir

c. Entrance Invert 2.7

d. Exit Invert 2.7

e. Emergency Draindown Facilities: Open Gate

HYDOMETEOROLOGICAL GAGES: None

a. Type N/A

b. Location N/A

c. Records N/A

MAXIMUM NON-DAMAGING DISCHARGE:

(Lake Stage Equal to Top of Dam) 1350 c.f.s.

APPENDIX 4

Hydraulic/Hydrologic Computations

HYDROLOGY:

HYDROLOGIC ANALYSIS

THE RUNOFF HYDROGRAPH WILL BE DEVELOPED BY THE HEC-1-DAM COMPUTER PROGRAM USING THE SCS METHOD WITH CURVILINEAR TRANSFORMATION

DRAINAGE AREA = 3.81 SQ MI

INFILTRATION DATA

INITIAL INFILTRATION - 1.5 inches

CONSTANT INFILTRATION - 0.15 inches/hour

TIME OF CONCENTRATION

1. [by SCS - TR 55]

OVERLAND FLOW :

length	=	4,500	[FT]
ave. slope	=	1.1	[%]
$\Delta H = 110' - 60' = 50'$			
ave. velocity	=	0.26	[F.p.s]

CHANNEL FLOW :

length	=	12 500	[FT]
ave. slope	=	0.4	[%]
$\Delta H = 60' - 8' = 52''$			
ave velocity	=	2.2	[F.p.s]

$$T_C = \left[\left(\frac{4500}{0.26}\right) + \left(\frac{12\,500}{2.8}\right)\right]\frac{1}{3600} = 4.8 + 1.6$$

$T_C = 6.4$ Hr.

2. ["Handbook of applied hydrology" by Chow - Pg 14-36]

$$T_C = \sqrt[2.14]{\tfrac{2}{3} L\eta / \sqrt{S}}$$

$$T_C = \sqrt[2.14]{2/3\,(4500 \times 0.4)} \Big/ \sqrt{0.011}$$

T_C = time of concentration [min]
S = slope [%]
η = 0.4 roughness coefficient
L = length of overland flow [ft]

$T_C = 78.42$ min $= 1.3$ Hr.

$T_C = 1.3 + 1.6 = 2.9$ Hr.

3. [by 'Design of small dams' Pg 71]

$$T_c = \left(\frac{11.9 (L)^3}{H}\right) 0.385$$

$$T_c = \left(\frac{11.9 \times (3.22)^3}{102}\right) 0.385$$

T_c = 1.7 Hr.

T_c = time of concentration [Hr]

L = longest watercourse [Mi]

H = elev. difference [Ft]

L = 3.22 [Mi]

H = 102 [Ft]

FOR COMPUTER INPUT

LAG TIME = 60% T_c = 4.0 × 0.6

LAG TIME = 2.4 Hr.

24 HOUR, 100 YEAR RAINSTORM DISTRIBUTION FOR CRYSTAL LAKE DAM

TIME (Hr.)	RAIN (in.)
1	0.08
2	0.08
3	0.08
4	0.08
5	0.08
6	0.08
7	0.09
8	0.09
9	0.18
10	0.18
11	0.18
12	0.19
13	0.3
14	0.3
15	0.8
16	3.0
17	0.4
18	0.3
19	0.19
20	0.18
21	0.09
22	0.09
23	0.08
24	0.08

Σ 7.20 inches

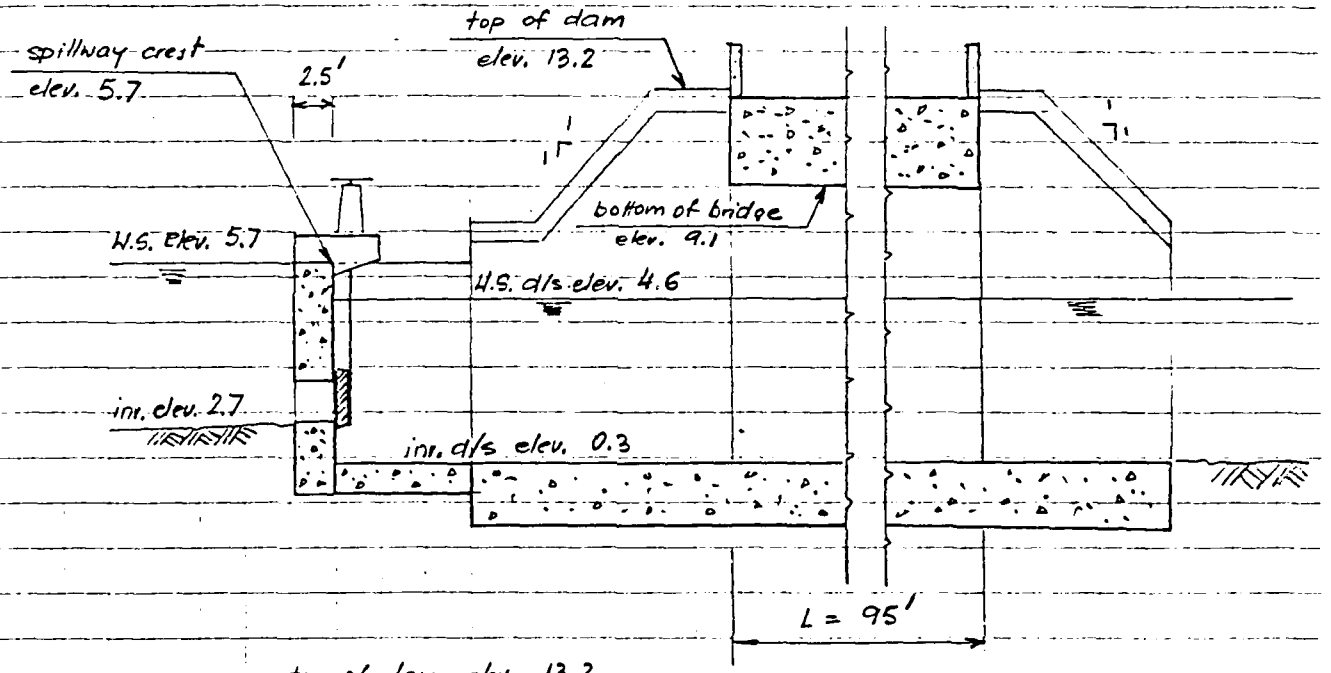
LAKE STORAGE VOLUME

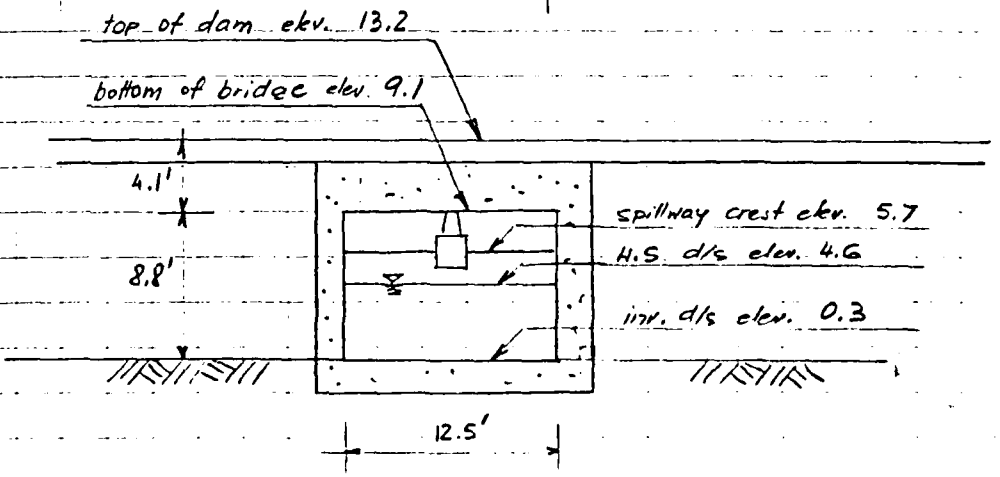
W. S. ELEV. [FT]	AREA [Acres]
0.3	0
5.7	27.6
10.0	57.4
20.0	122.6
30.0	185.5

HEC-1-DAM COMPUTER PROGRAM WILL DEVELOP STORAGE CAPACITY FROM WATER SURFACE AREAS AND ELEVATIONS. INFORMATION TAKEN FROM U.S.G.S. QUADRANGLE COLUMBUS & TRENTON EAST, N.J.

HYDRAULICS

THE SPILLWAY AT THE CRYSTAL LAKE DAM IS A CONCRETE FREE OVERFLOW BROAD CRESTED WEIR WITH A CREST ELEV. 5.7 FEET AND WITH AN EFFECTIVE LENGTH OF 36.0 FEET





DISCHARGE CALCULATION

[Handbook of hydraulics Pg 5-3]

DISCHARGE WILL BE CALCULATED FROM SPILLWAY CREST ELEV. 5.7 FEET UP TO THE BOTTOM OF THE BRIDGE AT ELEV. 9.1 FEET USING FORMULA

$Q = CLH^{3/2}$

Q = discharge [cfs]
C = coefficient of discharge
L = effective length of spillway [Ft]
H = total head on spillway [Ft]

[HCS - Highway culverts Pg 5-21]

AND FROM ELEV. 12.0 FEET AND ABOVE USING BOX CULVRET INLET CONTROL NOMOGRAPH
concrete box 12.5' x 8.8' & L = 95'

SPILLWAY
STAGE DISCHARGE TABULATION

W.S. ELEV. [Ft.]	Spillway L = 36.0' H [Ft]	C	Q [cfs]	INLET CONTROL Q [cfs]	ΣQ [cfs]
5.7	0	0	0		0
6.0	0.3	2.54	15.0		15.0
7.0	1.3	2.66	142.0		142.0
8.0	2.3	2.84	357.0		357.0
9.1	3.4	3.16	713.0	750.0	713.0
10.0	4.3	3.32	1065.0	938.0	938.0
11.0	5.3	3.32	1458.0	1052.0	1052.0
12.0				1187.0	1187.0
13.2				1350.0	1350.0
14.0				1450.0	1450.0
15.0				1550.0	1550.0
16.0				1650.0	1650.0

STORCH ENGINEERS

Project 1132-06 CRYSTAL LAKE DAM

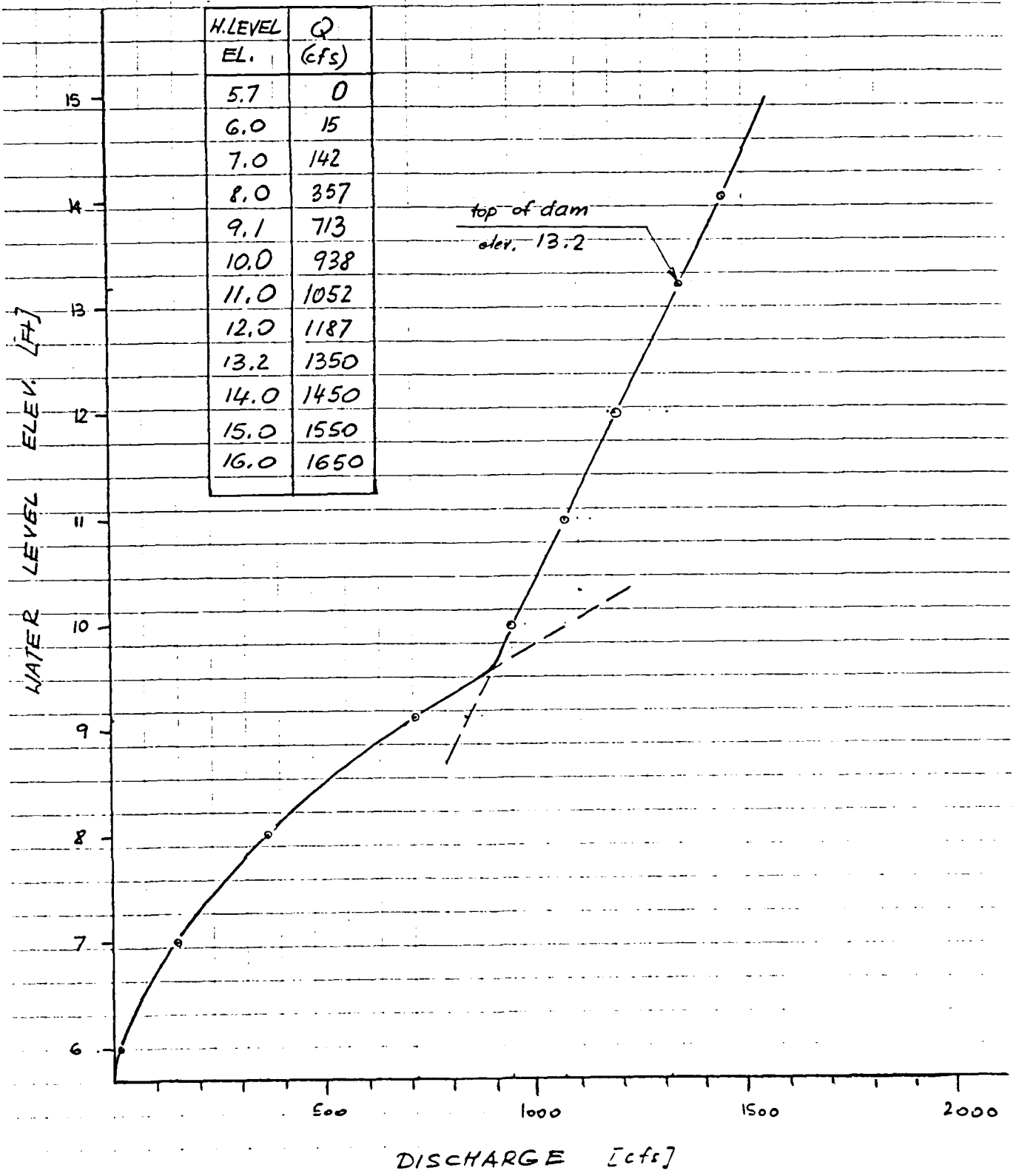
Sheet 8 of 10

Made By JHa Date 3-12-81

Chkd By JG Date 3/23/81

SPILLWAY
STAGE DISCHARGE CURVE

H.LEVEL EL.	Q (cfs)
5.7	0
6.0	15
7.0	142
8.0	357
9.1	713
10.0	938
11.0	1052
12.0	1187
13.2	1350
14.0	1450
15.0	1550
16.0	1650



STORCH ENGINEERS

Sheet 7 of 10

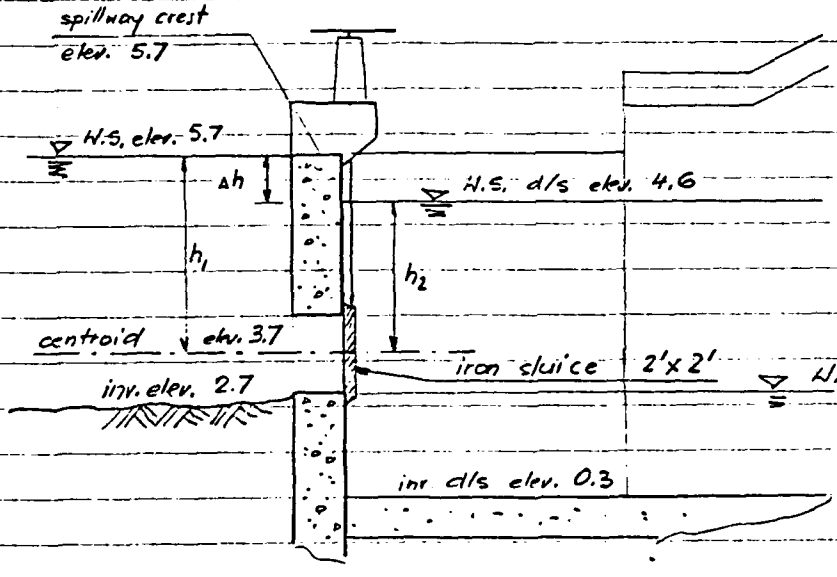
Project 1132-06 CRYSTAL LAKE DAM Made By J.Ha Date 3-12-81

Chkd By JG Date 3/23/81

DRAWDOWN

[Handbook of hydraulics, Pg 4-11]

THE DRAWDOWN DISCHARGE WILL BE CALCULATED FOR SHARP-EDGED (SUBMERGED) ORIFICE WITH DEFFERENT WATER SURFACE ELEVATIONS



USING FORMULA:

$C = 0.6$

$a = 2' \times 2' = 4\ Ft^2$

$\Delta h = h_1 - h_2 = 1.1'$

$Q = Ca\sqrt{2g\Delta h}$

$Q = 0.6 \times 4\sqrt{2 \times 32.2 \times 1.1}$

$Q = 20.0$ cfs

$h_1 = 2.0'$

$Q_{TOTAL} = 0.6 \times 4\sqrt{32.2 \times 2 \times 2.0}$

$Q_{TOTAL} = 27.0$ cfs

Q = discharge [cfs]

C = coefficient of discharge

g = 32.2

a = area of discharge [Ft²]

Δh = difference of heads to centroid [Ft]

TIME OF DRAWDOWN

$$Td = \frac{\text{storage [Ac-ft]}}{\text{Ave. discharge - inflow [cfs]}} \times \frac{43560}{3600}$$

Assume inflow 5.0 cfs

for $\Delta h = 1.1'$

$$Td = \frac{50}{20.0 - 5.0} \times \frac{43560}{3600} = 40 \text{ [Hr]}$$

for $h_1 = 2.0'$

$$Td = \frac{50}{27.0 - 5.0} \times \frac{43560}{3600} = 27.5 \text{ [Hr]}$$

HEC - 1 - DAM PRINTOUT

Overtopping Analysis

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IA1                        NATIONAL DAM SAFETY PROGRAM
A2                         CRYSTAL LAKE DAM, NEW JERSEY
A3                        100 YEAR STORM ROUTING
R      300         0        15                                                  4
B1       5
J        1         1         1
J1       1
K        0      LAKE                                          1
K1                        INFLOW HYDROGRAPH TO CRYSTAL LAKE DAM
M        0         2      3.81                3.81                           1
O       96
O1  0.019     0.019     0.019     0.019     0.019     0.019     0.019     0.019     0.019     0.019
O1  0.019     0.019     0.019     0.019     0.019     0.019     0.019     0.019     0.019     0.019
O1  0.019     0.019     0.019     0.019     0.019     0.019     0.019     0.019     0.019     0.019
O1  0.019     0.019     0.019     0.019     0.019     0.019     0.019     0.019     0.019     0.019
O1  0.019     0.019     0.019     0.019     0.019     0.019     0.019     0.019     0.038     0.038
O1  0.038     0.038     0.038     0.038     0.038     0.038     0.038     0.038     0.038     0.038
O1  0.083     0.083     0.083     0.083     0.163     0.163     0.163     0.163     0.750     0.750
O1  0.750     0.750     0.163     0.163     0.163     0.163     0.083     0.083     0.083     0.083
O1  0.083     0.083     0.083     0.083     0.038     0.038     0.038     0.038     0.038     0.038
O1  0.038     0.038     0.038     0.038     0.038     0.038
I                                                              1.5      0.15
W2                 2.4
X     -1.0     -0.05      2.0
K        1       DAM
K1                        ROUTE DISCHARGE THROUGH DAM
Y                                      1         1
Y1       1                                                   -5.7        -1
Y4     5.7       6.0       7.0       8.0       9.1      10.0      11.0      12.0      13.2      14.0
Y4    15.0      16.0
Y5       0        15       142       357       713       938      1052      1187      1350      1450
Y5    1550      1650
$A       0      27.6      57.4     122.6     185.5
$E     0.3       5.7      10.0      20.0      30.0
$$     5.7
$D    13.2       2.7       1.5       478
$B     200         1       0.5       1.0       5.7      13.2
K       99
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                    NATIONAL DAM SAFETY PROGRAM
                    CRYSTAL LAKE DAM, NEW JERSEY
                    100 YEAR STORM ROUTING

                         JOB SPECIFICATION
   NQ      NHR     NMIN     IDAY     IHR     IMIN    METRC    IPLT    IPRT    NSTAN
  300        0       15        0       0        0        0       0       4        0
                           JOPER     NWT    LROPT    TRACE
                               5       0        0        0

                    MULTI-PLAN ANALYSES TO BE PERFORMED
                         NPLAN= 1 NRTIO= 1 LRTIO= 1
        RTIOS=   1.00

 **********       **********       **********       **********       **********

                         SUB-AREA RUNOFF COMPUTATION

                    INFLOW HYDROGRAPH TO CRYSTAL LAKE DAM

              ISTAQ    ICOMP    IECON    ITAPE     JPLT     JPRT    INAME   ISTAGE   IAUTO
               LAKE        0        0        0        0        0        1        0       0

                              HYDROGRAPH DATA
      IHYDG    IUHG    TAREA    SNAP    TRSDA    TRSPC    RATIO    ISNOW    ISAME    LOCAL
          0       2     3.81    0.00     3.81     0.00    0.000        0        1        0

                                 LOSS DATA
  LROPT   STRKR   DLTKR   RTIOL   ERAIN   STRKS   RTIOK   STRTL   CNSTL   ALSMX   RTIMP
      0    0.00    0.00    1.00    0.00    0.00    1.00    1.50     .15    0.00    0.00

                              UNIT HYDROGRAPH DATA
                         TC=  0.00     LAG=  2.40

                                RECESSION DATA
                    STRTQ=    -1.00    QRCSN=     -.05    RTIOR= 2.00

      0
 MO.DA   HR.MN  PERIOD    RAIN    EXCS    LOSS       END-OF-PERIOD FLOW
                                                     COMP Q      MO.DA   HR.MN  PERIOD    RAIN    EXCS    LOSS     COMP Q

                                                                                 SUM    7.12    4.33    2.79     43762.
                                                                                     ( 181.)( 110.)(  71.)( 1239.20)
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HYDROGRAPH ROUTING

ROUTE DISCHARGE THROUGH DAM

ISTAO	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
DAM	1	0	0	0	0	0	0	0

ROUTING DATA

QLOSS	CLOSS	AVG	IRES	ISAME	IOPT	IPMP	LSTR
0.0	0.000	0.00	1	1	0	0	0

NSTPS	NSTDL	LAG	AMSKK	X	TSK	STORA	ISPRAT
1	0	0	0.000	0.000	0.000	-6.	-1

STAGE	5.70	6.00	7.00	8.00	9.10	10.00	11.00	12.00	13.20	14.00
	15.00	16.00								
FLOW	0.00	15.00	142.00	357.00	713.00	938.00	1052.00	1187.00	1350.00	1450.00
	1550.00	1650.00								
SURFACE AREA=	0.	28.	57.	123.	186.					
CAPACITY=	0.	50.	229.	1108.	2638.					
ELEVATION=	0.	6.	10.	20.	30.					

CREL	SPWID	COOW	EXPW	ELEVL	COOL	CAREA	EXPL
5.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DAM DATA

TOPEL	COOD	EXPD	DAMWID
13.2	2.7	1.5	478.

DAM BREACH DATA

BRWID	Z	ELBM	TFAIL	WSEL	FAILEL
200.	1.00	.50	1.00	5.70	13.20

PEAK OUTFLOW IS 1327. AT TIME 22.00 HOURS

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE MILES (SQUARE KILOMETERS)

OPERATION	STATION	AREA	PLAN	RATIOS APPLIED TO FLOWS RATIO 1 1.00
HYDROGRAPH AT	LAKE	3.81 ([illegible])	1	2613. (74.00)(
ROUTED TO	DAM	(9.87)	1	1327. (37.57)(

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SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1		INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
	ELEVATION	5.70	5.70	13.20
	STORAGE	50.	50.	441.
	OUTFLOW	0.	0.	1350.

	RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
	1.00	13.03	0.00	428.	1327.	0.00	22.00	0.00

APPENDIX 5

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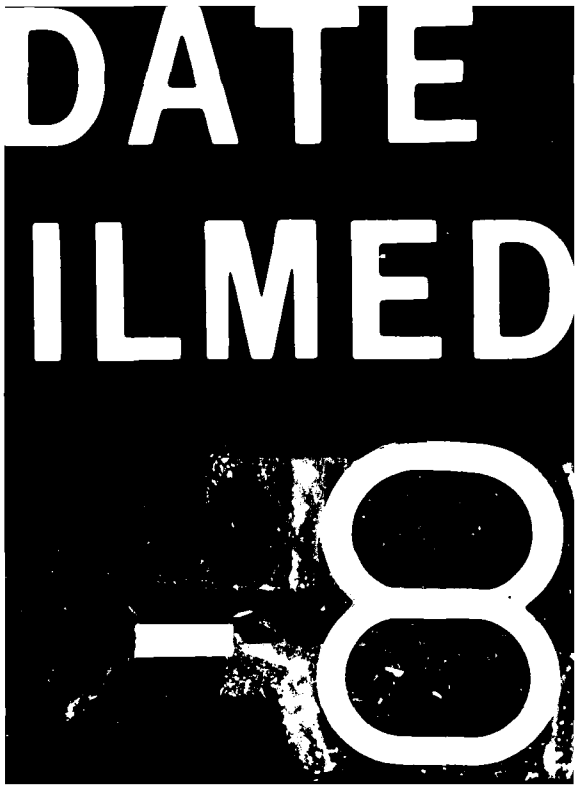
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